CALIFORNIA DIVISION OF MINES AND GEOLOGY
FAULT EVALUATION REPORT FER-147

Bear Mountain Fault Zone, Auburn Area

by

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1. Name of faults

Highway 49, Deadman, Maidu, Hancock Creek, Pilot Hill, Salt Creek, Knickerbocker Creek, F-zones, and Maidu East segments of the Bear Mountain fault zone.

2. Location of faults

Lake Combie, Auburn, and Pilot Hill 7.5-minute quadrangles, Nevada, Placer, and El Dorado counties (figure 1).

3. Reason for evaluation

Part of the 10-year fault evaluation program (Hart, 1980).

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5. Review of Available Data

The Foothills fault system in the western Sierra Nevada, first named by Clark (1960), was not considered to be recently active prior to the 1975 M5.7 Oroville earthquake. Surface fault rupture along the Cleveland Hill fault zone was associated with the Oroville earthquake, and, subsequently, was zoned for Special Studies on January 1, 1977. As a result of the Oroville earthquake, geotechnical investigations for the proposed Auburn Dam were greatly expanded. Woodward-Clyde Consultants (WCC), under contract for the U.S. Bureau of Reclamation (USBR), conducted detailed studies of the Auburn damsite, but also investigated earthquake hazards elsewhere in the western foothills of the Sierra Nevada. Thus, significant new data on recently active faults in the foothills were developed. Selected segments of the Foothills fault system from Sonora north to near Oroville will be evaluated in three Fault Evaluation Reports (FER). This FER will evaluate fault zones in the Auburn area, including the Highway 49, Deadman, Maidu, Maidu East, Hancock Creek, Pilot Hill, Salt Creek, and Knickerbocker Creek fault zones (figure 1).

The Foothills fault system consists of the Melones fault zone on the east and the Bear Mountain fault zone on the west (Clark, 1960, 1964, 1976; Cebull, 1972, Duffield and Sharp, 1975). Faults within the FER study area include segments of the Bear Mountain fault zone. The Foothills fault system was generated by eastward plate convergence and subduction during early Mesozoic time (Hamilton, 1969; Schweickert and Cowan, 1975; Clark, 1976). This episodic period of plate convergence produced the dominant structural features in the western Sierran foothills and the Foothills fault system. In general, structural elements that comprise the Foothills fault system are subparallel to regional foliation and cleavage. This has resulted in a strong structural grain dominated by planar elements that strike north-northwest and generally dip steeply eastward.

Superimposed on this compressional structural fabric is a period of late Cenozoic east-west extension (Alt, et al., 1977). This east-west extension has resulted in high-angle normal faults that occur along pre-existing Paleozoic and Mesozoic structures (Alt, et al., 1977). However, Alt, et al. found evidence indicating that late-Cenozoic activity has not occurred along all pre-existing faults of the Foothills fault system.

Rock types in the FER study area consist predominantly of Late Jurassic metavolcanic and metasedimentary rocks, Paleozoic metasedimentary rocks, minor outcrops of granitoid rocks of the Rocklin pluton, and isolated outcrops of Miocene-Pliocene Mehrten Formation (Burnett and Jennings, 1962; Wagner, et al., 1981; Alt et al., 1977). A characteristic problem with evaluating recent fault activity in the western Sierran foothills is the general lack of Tertiary and Quaternary material overlying much of the Mesozoic bedrock.

Remnants of a paleo-B soil horizon developed in Mesozoic bedrock locally occur in the western Sierran foothills. This paleosol is thought by WCC to have formed about 100,000 years B.P. (Swan and Hanson, 1977). However, the U.S. Geological Survey (1978) and Borchardt, et al. (1980b) suggest that the foothills paleosol was actively developing from about 140,000 years to 10,000 years B.P. They reason that the paleosol probably began to form about 100,000 years to 140,000 years ago and continued to develop until eroded or deeply buried by younger deposits. Therefore, its age extends to the age of the overlying erosion surface or deposits. In many places, the overlying deposit is what Borchardt, et al. term the foothills colluvium, a relatively unweathered colluvium thought to have formed about 9,000 years B.P. (Swan and Hanson, 1977; Borchardt, et al., 1980b).

Land surfaces in the FER study area have been modified to varying degrees by grading. The Auburn area has been modified by cultural development, and the Auburn damsite along the American River has been extensively modified by grading and detailed geological investigations. Topography in the study area is characterized by linear ridges and valleys reflecting the strong northwest-trending Mesozoic structural fabric. Massive landsliding in the area generally is not widespread, but local soil creep and expansive soils have affected or modified soil-bedrock relationships.

Slip rates on the order of magnitude of about 0.005 mm/yr (Schwartz, et al., 1977; Bryant, 1983) are characteristic of potentially active faults in the western Sierran foothills from Oroville to north of Auburn. Faults in this area between Oroville and Auburn were evaluated in FER-146 (Bryant, 1983), and it was concluded that these faults did not meet the zoning criteria of sufficiently active and well-defined (Hart, 1980). Based on the results of FER-146 and limited time constraints, this FER will be limited to a literature review and very brief air photo interpretation.

Highway 49 Lineament

The Highway 49 lineament is a prominent, north-northeast trending feature north of Auburn (figure 1). Burnett and Jennings (1962) and Clark (1976) mapped a northeast-trending fault parallel to Highway 49 that partly coincides with the Highway 49 lineament mapped by WCC (Alt, et al., 1977). Burnett and Jennings identify rocks west of the fault zone as Paleozoic metasedimentary rocks, although Clark (1976) identifies these rocks as Late Jurassic in age.

Trenching across the Highway 49 fault zone was conducted by WCC at the Smith property site (figures 3, 4). Three test pits and one trench were excavated across a groundwater barrier (linear tonal contrast). The trench exposed Mesozoic metasedimentary rocks faulted against phyllite. The fault strikes N0° to 5°W and dips 45° to 55°W along a well-developed slickensided plane. The sense of displacement, based on bedrock evidence, is not clear. A remnant paleo-B soil horizon was observed east of and against the fault in the north wall of the trench. The paleosol was observed to the east of the fault in the south wall of the trench, but it was not preserved directly adjacent to the fault. The paleosol exposed in the north wall is faulted against brecciated metasedimentary rock in an apparent reverse sense (up on the west) (figure 5). The west-dipping fault plane extends into the paleosol, but alluvium overlying the paleosol is not offset. Borchardt, et al. (1980b) assigned an early Holocene age to the alluvium and indicate that the paleosol may have formed during the Wisconsin Period (10,000-130,000 years B.P.), or perhaps, during the interglacial period preceding the Wisconsin.

WCC (Alt, et al., 1977) postulated an apparent reverse displacement of the paleosol of about 0.7 foot, down to the east. This displacement was inferred by projecting the base of the paleosol exposed in the south wall of the trench and measuring the step of the base of the paleosol exposed in the north wall of the trench.

Deadman Lineament

The Deadman lineament zone is a broad, northwest-trending zone generally defined by linear ridges and valleys (figure 1). Clark and Huber (1975) mapped shear zones in Mesozoic bedrock exposed along the Bear River that are coincident with the Deadman lineament. WCC (Schwartz, et al., 1977) conducted two site investigations along the Deadman lineament; the Henriques/Wilson and North Ravine exploration sites.

The Henriques/Wilson exploration site is located along the westernmost segment of the Deadman lineament (figure 6). WCC (Schwartz, et al., 1977) excavated ten test pits along the western segment of the Deadman lineament. Two test pits exposed evidence of faults that coincided with tonal lineaments. Quaternary stratigraphy is very sparse at this site, and WCC was unable to evaluate recency of faulting.

The North Ravine exploration locality encompasses four segments of the Deadman lineament (figure 1). Bedrock structures are poorly exposed along these segments; however, WCC did not excavate trenches in this area, and they made no evaluation of fault activity.

Maidu Lineament

The Maidu lineament is a northwest-trending structural feature that is located in and north of Auburn (figures 6, 8b). WCC (Schwartz, et al., 1977) excavated test pits, and two trenches excavated by USBR (ST-68 and ST-87) crossed the Maidu lineament (figure 8b). Conclusive evidence for or against late-Cenozoic faulting was not obtained at the Maidu exploration locality. WCC (Schwartz, et al., 1977) concluded that "...The available data suggest the Maidu lineament zone is not coincident with a major fault displacing the Mehrten Formation. The aligned breaks in slope and topographic depressions that define the lineament zone in the Mehrten Formation may be related to differential weathering and erosion of subhorizontal Mehrten Formation units, or to differential weathering and erosion of primary depositional features (cut fill channels) of the Mehrten Formation."

Hancock Creek Lineament

The Hancock Creek lineament trends north-south and is generally on trend with faults mapped by Clark (1960) and Olmsted (1971) (figure 1). Mapping by WCC (Schwartz, et al., 1977) indicates that the Hancock Creek lineament generally coincides with zones of Mesozoic shearing. However, WCC was not able to evaluate recent fault activity because well-defined "linear elements" were not observed.

Pilot Hill Lineament

The Pilot Hill lineament (figures 1 and 2) trends south-southeast and generally is on-trend with a Mesozoic shear zone mapped by Olmsted (1971).

The Pilot Hill lineament may be the southern extension of the Maidu lineament zone (Schwartz, et al., 1977). WCC (Schwartz, et al., 1977) conducted site specific investigations at two localities along the Pilot Hill lineament: the Pilot Hill and Salmon Falls sites (figure 1). Test pits were excavated at both sites, and results generally were inconclusive because Quaternary stratigraphy was sparse or absent. Well-defined continuous fault zones were not observed, and WCC did not evaluate recency of fault activity for this area.

Salt Creek and Knickerbocker Creek Lineaments

The Salt Creek lineament zone is a major north-northwest trending feature in and south of Auburn (figure 1). Olmsted (1971) mapped a shear zone in bedrock that partly coincides with the Salt Creek lineament. WCC (Schwartz, et al., 1977) conducted investigations along the Salt Creek lineament at the Bayley House and Salt Creek exploration sites (figures 1, 7). Evidence of late-Cenozoic faulting was not observed in trenches excavated at the Bayley House site (figure 7). WCC (Schwartz, et al., 1977) concluded that linear features at the Bayley House exploration site were not fault related. WCC excavated five test pits at the Salt Creek exploration site. These excavations did not expose evidence of faulting, although the test pits were shallow, and adequate Quaternary stratigraphy was not present. Thus, no evaluation of fault activity was made by WCC.

The Knickerbocker Creek lineament trends northwest from the Salt Creek lineament and may connect with the F-0 fault zone mapped by USBR (figures 1, 6, 7, and 8b). Three trenches excavated by USBR (ST-102, ST-103, BHT-89) exposed faults in Mesozoic bedrock. These faults have characteristics similar to other late-Cenozoic faults observed in the western Sierran foothills. However, a paleo-B soil horizon was not observed in the trenches, and colluvium overlying the faults was not offset. WCC concluded that, based on mapping by USBR, the Knickerbocker Creek lineament was not a southeastern continuation of the F-0 fault zone (Schwartz, et al., 1977).

F-zones

USBR (Frei, et al., 1977) mapped at least 37 F-zones (fault zones) in and near the Auburn damsite. Two dominant faults (F-0 and F-1) crosscut regional foliation and pass beneath or very near the proposed dam foundation (figure 6). Consequently, these west-northwest trending, southwest-dipping faults have been the subject of very critical study. Quaternary stratigraphy overlying these faults is only sparsely preserved, so an objective evaluation of fault recency is difficult to make.

Borchardt, et al. (1980b) describe a fault exposure in a railroad embankment 2 km northwest of the Auburn dam foundation. They suggest that this fault is the western continuation of F-0. A paleo-B soil horizon was observed on the northeast side of the fault, but it did not occur on the southwest side (hanging wall) of the fault. Colluvium overlies the fault and is not offset. Borchardt, et al. (1980b) concluded that post-Illinoian (130,000 year B.P.) faulting may have occurred along this fault, but there is no evidence for Holocene activity.

F-1 is a sinuous, west-northwest trending fault that passes beneath the proposed Auburn dam foundation (figure 6). In the left abutment of the dam foundation, a steeply dipping shear displaces F-1. The latest movement along F-1 offsets the steeply dipping shear about 2 to 3 feet in a left-lateral sense (Behrman and Meyer, 1977; Schwartz, et al.; Ostenaa and

Throner, 1978). However, the date of this most recent displacement along F-1 cannot be accurately assessed. WCC concluded that structural relationships and fault characteristics of F-1 are similar to other late-Cenozoic faults in the western Sierran foothills (Schwartz, et al., 1977). Behrman and Meyer (1977) state that the most recent offset along F-1 can only be bracketed between 120± 6 m.y. and the present.

The USGS (1978) basically concurs with conclusions of WCC. However, the USGS points out that gouge zones, slickensides, and striations associated with recent movement along F-1 may, in fact, be related to landsliding along a pre-existing fault surface. Although displacement along F-1 is left-lateral with a reverse component, several sets of slickensides and striations are compatible with oblique displacement downslope toward the American River (USGS, 1978).

Maidu East Lineament

The Maidu East lineament is an approximately 3,700-foot long, north-northeast trending feature first mapped by WCC (Schwartz, et al., 1977) (figures 7, 8a). The southern projection of the Maidu East lineament coincides with a shear zone in Mesozoic quartz diorite mapped by USBR (Frei, et al., 1977). The Maidu East lineament passes from quartz diorite northward coincident with a talc/fault zone (T-25) mapped by USBR (figure 8b).

Extensive trenching along the Maidu East lineament was done by USBR (Frei, et al., 1977) and WCC (Schwartz, et al., 1977) (figure 8a). The Maidu East lineament is coincident with a fault zone that displaces the Mehrten Formation. Maximum vertical separation of about 18 feet, down to the east, was observed, and WCC estimates that about 31 feet of right-lateral oblique slip has occurred along the Maidu East fault (Schwartz, et al., 1977). Twenty-five trenches were excavated along the Maidu East lineament by WCC and USBR. Anomalous features in overlying colluvium and soils were observed in USBR trenches BHT-64, BHT-53, and in WCC trench GT-1 (figure 8a). WCC concluded that soil tongues along shear zones and steps in the base of the colluvium may be caused by recent faulting along the Maidu East lineament. If these features are tectonic, then about 1-1/2 to 2 feet of vertical slip, down to the east, has occurred along the Maidu East lineament within the last 100,000 years, possibly within the last 40,000 years (Schwartz, et al., 1977). However, the origin of these features is not entirely clear and, according to WCC, may have been produced by surficial weathering and soil-forming processes.

Both Shlemon (1977a, 1977b, 1978) and Borchardt, et al., (1980a) consider the anomolous soil/colluvium features exposed in trench BHT-53 to be the result of pedogenic processes rather than tectonic processes. Soil tongues observed in BHT-53 are considered to be the result of montmorillonite and halloysite formation under reducing conditions within pre-existing shears along the Maidu East lineament (Borchardt, et al., 1980a). An east-facing scarp associated with the Maidu East lineament is located about 30 meters west of the principal fault in the Mehrten Formation, indicating: 1) the scarp is a fault-line scarp, and 2) significant erosion has occurred since the original fault scarp formed. Initial interpretations by WCC and USGS indicated that a buried colluvial unit exposed in BHT-53 was displaced by faulting. However, further investigations by Borchardt, et al. (1980a) and Shlemon (1978) revealed that the colluvium does not directly overly the Mehrten Formation. A saprolite boundary is considered by Borchardt, et al. to delineate the base of the colluvium, and no offset of this boundary was observed (figure 9).

The best preserved Quaternary stratigraphy along the Maidu East lineament was exposed in USBR trench ST-65, located 800 feet north of BHT-53 (figure 8a). The principal fault related to the Maidu East lineament did not offset a paleo-B soil horizon. Shlemon (1978) concluded that faulting at this location has not occurred in the last 100,000 years. Borchardt, et al. (1980a) conclude that faulting along the Maidu East lineament probably has not occurred in the last 130,000 years, although small displacements within the last 100,000 years cannot be ruled out.

6. Air photo interpretation

Due to time constraints, air photo interpretation by this writer was limited to a brief verification of features mapped by others. Generally, lineaments were photo-checked only when trench data indicated that Quaternary-active faults were present.

Highway 49 Lineament

The Highway 49 lineament is a northeast-trending feature that generally corresponds to a fault zone mapped by Burnett and Jennings (1962) and Clark (1976). The lineament is characterized by a series of north-trending valleys, associated rounded hills, and aligned saddles. Linear tonal contrasts, vegetation lineaments, and groundwater barriers were observed within the lineament zone. Geomorphic evidence of Holocene-active reverse faulting, such as east-facing scarps and closed depressions, was not observed at the Smith property site (Alt, et al., 1977).

Deadman Lineament

The Deadman lineament is characterized by strong, northwest-trending linear ridges and valleys. Four segments within the Deadman lineament zone have been identified by WCC (Schwartz, et al., 1977). Three segments are delineated by linear valleys that contain discontinuous linear tonal contrasts, linear drainages, and groundwater barrier. Geomorphic evidence of recent faulting was not observed by this writer.

Maidu Lineament

The Maidu lineament is characterized by a linear valley and a sharp, well-defined vegetation contrast observed on 1938 USDA air photos. A linear depression observed by WCC (Schwartz, et al., 1977) may be a linear drainage modified by the construction of a railroad embankment, based on air photo interpretation by this writer. Well-defined geomorphic evidence of recently active faults was not observed south of the railroad embankment (figure 6).

Salt Creek Lineament

The Salt Creek lineament is generally characterized by a N30°W-trending linear valley. The Bayley House exploration site is characterized by linear tonal contrasts (groundwater barriers) within a broad linear valley (figures 6, 7). Geomorphic evidence of Holocene-active faulting was not observed. Trenches excavated across some of these groundwater barriers exposed intensely foliated rocks and lithologic contrasts, but no evidence of recent faulting. Well-defined geomorphic evidence of recent faulting was not observed at the Salt Creek exploration site (figure 7). Test pits excavated by WCC did not expose evidence of recent faulting (Schwartz, et al., 1977).

F-0 and F-1

The F-0 and F-1 fault zones generally are poorly defined. Geomorphic evidence of recent faulting along these faults was not observed by this writer (figure 6, 8b). However, these fault traces are located along the extremely steep slopes of the American River canyon where erosion rates far out-pace probable fault slip rates.

Maidu East Lineament

The Maidu East lineament is a north-northeast trending feature characterized by linear vegetation contrasts and a subtle east-facing scarp in the Miocene-Pliocene Mehrten Formation (figure 7). The geomorphic features are not continuous, and the east-facing scarp has been demonstrated to be a fault-line scarp that has receded about 30m west of the principal trace of the Maidu East fault (Borchardt, et al., 1980a). Systematic, well-defined geomorphic evidence of recent faulting (either vertical, or right-lateral) was not observed along the Maidu East lineament.

7. Seismicity and Crustal Monitoring

The northern Foothills fault system has a pattern of low-level seismicity (Cramer, et al., 1978; Marks and Lindh, 1978; Eaton and Simirenko, 1980). With the exception of the 1975 Oroville earthquake and aftershock sequence and seismicity in the Rocklin pluton, very little historic seismic activity has occurred along the northern Bear Mountain fault zone in the FER study area (figure 10).

First-order releveling surveys across segments of the Bear Mountain fault zone indicate that vertical deformation has occurred since initial surveys performed in 1947 (Bennett, 1978). This evidence of crustal strain is associated with recognized pre-Cenozoic faults within the Bear Mountain fault zone. Approximately 20 mm of down-to-the-west vertical deformation occurred along the Bear Mountain fault zone near Auburn between 1969 and 1977 (Bennett, 1978). This deformation occurred in a zone about 1-1/2 miles wide across and west of the Deadman lineament. Crustal strain associated with the Bear Mountain fault zone typically occurs in a zone up to four miles wide, indicating that strain is distributed over a broad zone rather than along discrete, well-defined faults.

8. Conclusions

Woodward-Clyde Consultants (Alt, et al., 1977; Schwartz, et al., 1977), under contract to USBR, conducted detailed studies of the Foothills fault system with respect to seismic safety for the proposed Auburn Dam. Regional studies along the northern extension of the Bear Mountain fault zone revealed evidence for late-Cenozoic extensional faulting along prominent north to northwest-trending regional lineaments that define fault zones formed during the Mesozoic Era.

Segments of the Bear Mountain fault zone evaluated in this FER are characterized by geomorphic features such as linear valleys, ridges, drainages, and aligned saddles. These large-scale geomorphic features reflect a near vertical northwest-trending structural fabric formed in Mesozoic time and are primarily erosional. These features are generally well-defined within a regional context, but are much less well-defined in detail. No geomorphic evidence of systematic recent normal faulting was observed along these fault zones. Geomorphic evidence delineating potentially active faults investigated by WCC was limited to linear tonal contrasts, vegetation contrasts, and springs (Schwartz, et al., 1977). This evidence is not mandatory of Holocene-active faulting, and tonal contrasts are common in the western Sierran foothills away from the major regional lineaments.

Crustal monitoring of the western Sierran foothills indicates that down-to-the-west deformation along the Bear Mountain fault zone has occurred near Auburn (Bennett, 1978). It is possible that this strain, reflecting current east-west extension, is distributive at the surface and is taken up along several pre-existing Mesozoic-age shear zones. Thus, if a discrete zone of deformation exists at depth, it may be manifested at the surface over a wide zone, perhaps several miles in width, with minor deformation occurring along several bedrock fault zones.

Highway 49 Lineament

The Highway 49 lineament is a north-northeast trending lineament that partly coincides with a fault zone mapped by Burnett and Jennings (1962) and Clark (1976). A trench excavated by WCC (Alt, et al., 1977) exposed a west-dipping reverse fault that apparently offsets a paleo-B soil horizon (figure 5). However, early Holocene alluvium is not offset by the fault (Borchardt, et al., 1980b). Geomorphic evidence characteristic of a Holocene-active reverse fault was not observed at the Smith property site.

Deadman Lineament Zone

The Deadman lineament zone consists of four northwest-trending segments generally characterized by linear valleys. Linear tonal contrasts and drainages occur within these broader lineament zones. WCC (Schwartz, et al., 1977) excavated test pits across some of these tonal lineaments. Shears in Mesozoic bedrock were exposed, but Quaternary stratigraphy is sparse; thus, WCC was unable to evaluate recency of faulting along the Deadman lineament zone. Well-defined geomorphic evidence of recent faulting was not observed along segments of the Deadman lineament zone, based on brief air photo interpretation by this writer.

Maidu Lineament

The Maidu lineament is a northwest-trending feature characterized by linear vegetation contrasts and subtle scarps in Miocene-Pliocene Mehrten Formation. Test pits excavated by WCC and trenches excavated by USBR did not reveal conclusive evidence for or against late-Cenozoic faulting. WCC concluded that the Maidu lineament is not coincident with a major fault displacing the Mehrten Formation. The Maidu lineament generally is not well-defined except for a sharp vegetation contrast near the fairgrounds (figure 6). A linear depression described by WCC (Schwartz, et al., 1977) was not verified by this writer (figure 6). The well-defined tonal lineament occurs in Mesozoic-age bedrock and does not indicate recent activity.

Hancock Creek Lineament

Mapping by Clark (1960) and Olmsted (1971) indicate that bedrock faults are generally on-trend with the Hancock Creek lineament. However, well-defined "linear elements" within the Hancock Creek lineament were not observed by WCC (Schwartz, et al., 1977). Thus, trenches or test pits were not excavated, and WCC made no evaluation of fault recency.

Pilot Hill Lineament

The Pilot Hill lineament trends north-northwest and generally corresponds to a Mesozoic shear zone mapped by Olmsted (1971). WCC (Schwartz, et al., 1977) excavated test pits across the Pilot Hill lineament at two locations (Pilot Hill and Salmon Falls sites, figure 7). Well-defined, continuous faults were not observed in the test pits, and Quaternary stratigraphy was sparse. WCC was unable to evaluate fault recency along the Pilot Hill lineament.

Salt Creek and Knickerbocker Creek Lineaments

The Salt Creek lineament is a major north-northwest trending feature that partly coincides with a bedrock shear zone mapped by Olmsted (1971) (figure 7). Exploration by WCC at the Bayley House site indicated that linear tonal contrasts within the Salt Creek lineament were not fault-related (Schwartz, et al., 1977). Evidence of late-Cenozoic faulting was not observed at the Salt Creek exploration site, although detailed excavations were not performed (Schwartz, et al., 1977) (figure 7).

The Knickerbocker Creek lineament trends northwest from the Salt Creek lineament and may connect with the F-O fault zone exposed in the Auburn dam foundation. USBR (Frei, et al., 1977) excavated three trenches across the Knickerbocker Creek lineament and exposed faults in Mesozoic bedrock. Paleosols were not observed in the trenches, but Holocene (?) colluvium was not offset. WCC (Schwartz, et al., 1977) concluded that: 1) although a paleo-B soil horizon was not preserved in the USBR trenches, the bedrock faults have characteristics similar to other late-Cenozoic faults observed in the western Sierran foothills, and 2) the Knickerbocker Creek lineament is not a southern extension of the F-O fault zone.

F-zones

Numerous fault zones observed in and adjacent to the Auburn dam foundation were labeled F-zones by the USBR. Two F-zones, F-O and F-1, were the subject of extensive investigations because they passed beneath the dam foundation (figure 8b). Quaternary stratigraphy is very sparse over much of the F-O and F-1 traces, and evaluation of fault recency is judgmental at best. However, USBR trenched the western part of F-O (BHT-76, 77, 86, 100), and a discontinuous paleo-B soil horizon was exposed. Evaluation of fault recency could not be made, but an exposure of a faulted paleosol along a westward projection of F-O was described by Borchardt, et al. (1980b). A southwest-dipping fault in bedrock is similar to the orientation of F-O observed in the dam foundation. Colluvium overlying the fault of Borchardt, et al. is not offset, and they concluded that latest displacement along this fault is post-Illinoian (130,000 years) and pre-Holocene.

F-1 is a generally northwest-trending, southwest-dipping left-lateral oblique fault (Schwartz, et al., 1977; USGS, 1978). Evaluation of the most recent displacement along F-1 could not be made, although WCC concluded that F-1 has characteristics similar to late-Cenozoic faults observed elsewhere in the western Sierran foothills. USGS (1978) generally agrees with WCC's conclusions, although USGS considers the evidence for the most recent displacements along F-1 to be equally compatible with landsliding toward the American River.

Both F-0 and F-1 are poorly defined faults, based on brief air photo interpretation by this writer.

Maidu East Lineament

The Maidu East lineament is a 3,700-foot long, north-northeast trending feature (figures 7, 8a). Twenty-five trenches were excavated by USBR and WCC across the Maidu East lineament. Miocene-Pliocene-age Mehrten Formation has been displaced about 31 feet in a right-lateral oblique sense (Schwartz, et al., 1977). Distinctive "soil tongues" observed in trenches BHT-53, BHT-64, and GT-1 may indicate recent faulting, but Shlemon (1977a, 1977b, 1978) and Borchardt, et al. (1980a) conclude that they are pedogenic features unrelated to recent faulting. The bedrock-colluvium contact overlying the Maidu East fault may be offset about 1-1/2 to 2 feet (down to the east), although Borchardt, et al. (1980a) identify a saprolite boundary as the base of the colluvium. The saprolite boundary is not displaced across the Maidu East fault. USBR trench ST-65, located 800 feet north of BHT-53, exposed a well-developed paleo-B soil horizon overlying the Maidu East fault. The paleosol was not displaced. Shlemon (1978) and Borchardt, et al. (1980a) conclude that faulting along the Maidu East lineament has probably not occurred in the last 100,000 years to 130,000 years.

The Maidu East lineament is characterized by vegetation lineaments and a subtle east-facing scarp. The scarp was shown to be a fault-line scarp that has receded about 30 meters west of the principal trace of the Maidu East fault (Borchardt, et al., 1980a). Well-defined geomorphic evidence of recent faulting was not observed along the Maidu East fault.

Holocene faulting along segments of the Bear Mountain fault zone in this FER study area cannot be ruled out, based on investigations by WCC and USBR (Schwartz, et al., 1977; Borchardt, et al., 1980a, 1980b). However, the individual faults are not well-defined in detail, and, if any of the faults are active, rates of displacement (on the order of 0.005 mm/yr) along individual faults probably are not large enough to produce significant amounts of suface rupture. In addition, the general lack of Quaternary deposits along most of these fault zones severely limits the chances of meaningful active fault evaluation.

9. Recommendations

Recommendations for zoning faults for special studies are based on the criteria of "sufficiently active" and "well-defined" (Hart, 1980).

Highway 49 Lineament

Do not zone for special studies. Well-defined geomorphic evidence of Holocene-active faulting was not observed, and an early Holocene alluvial deposit is not offset.

Deadman Lineament

Do not zone for special studies. Geomorphic features are not well-defined in detail, and there is no evidence for Holocene activity.

Maidu Lineament

Do not zone for special studies. Geomorphic evidence for Holocene faulting was not observed, and there is no evidence of significant post-Mehrten offset.

Hancock Creek Lineament

Do not zone for special studies. This fault is not well-defined.

Pilot Hill Lineament

Do not zone for special studies. This fault is not well-defined.

Salt Creek and Knickerbocker Creek Lineaments

Do not zone for special studies. Evidence for late-Cenozoic offset was not observed along the Salt Creek lineament. Holocene colluvium was not offset along the Knickerbocker Creek lineament, and both lineaments are not well-defined in detail.

F-O and F-1

Do not zone for special studies. These faults are not well-defined and are probably pre-Holocene.

Maidu East Lineament

Do not zone for special studies. This fault is not well-defined, and there is no evidence of Holocene activity.

10. Report prepared by William A. Bryant, July 7, 1983.

I agree with the recommendations
Earl W. Hart
CEG 935
7/18/83

William A. Bryant

William A. Bryant
Associate Geologist
R.G. #3717
July 7, 1983

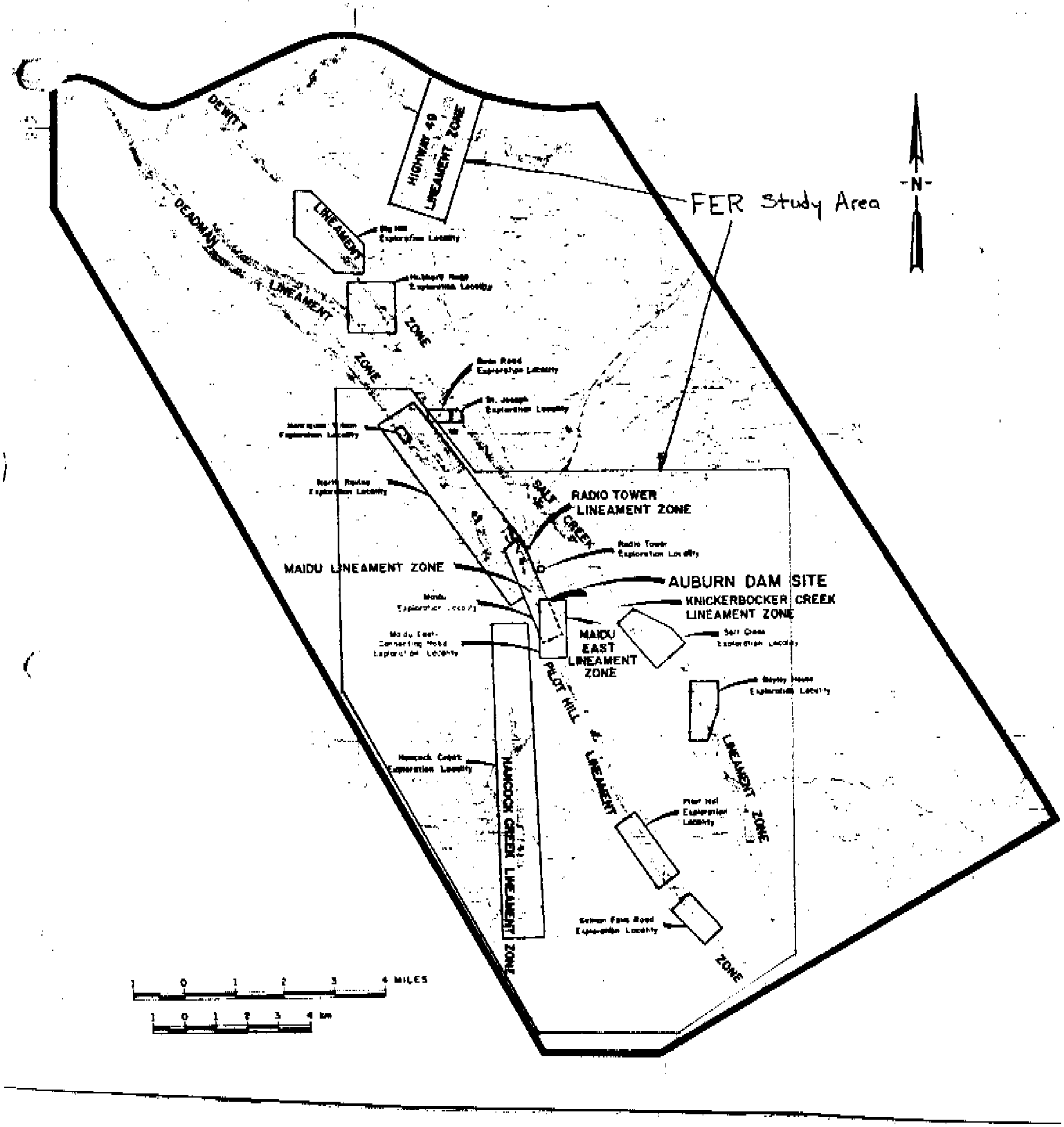

Figure 1 (to FER-147). Generalized map of lineaments within the Bear Mountain fault zone, showing locations of site specific investigations conducted by WCC. The Highway 49, Deadman, Maidu, Hancock Creek, Pilot Hill, Salt Creek, Knickerbocker Creek, and Maidu East lineaments are evaluated in this FER. Map from Schwartz, et al. (1977).

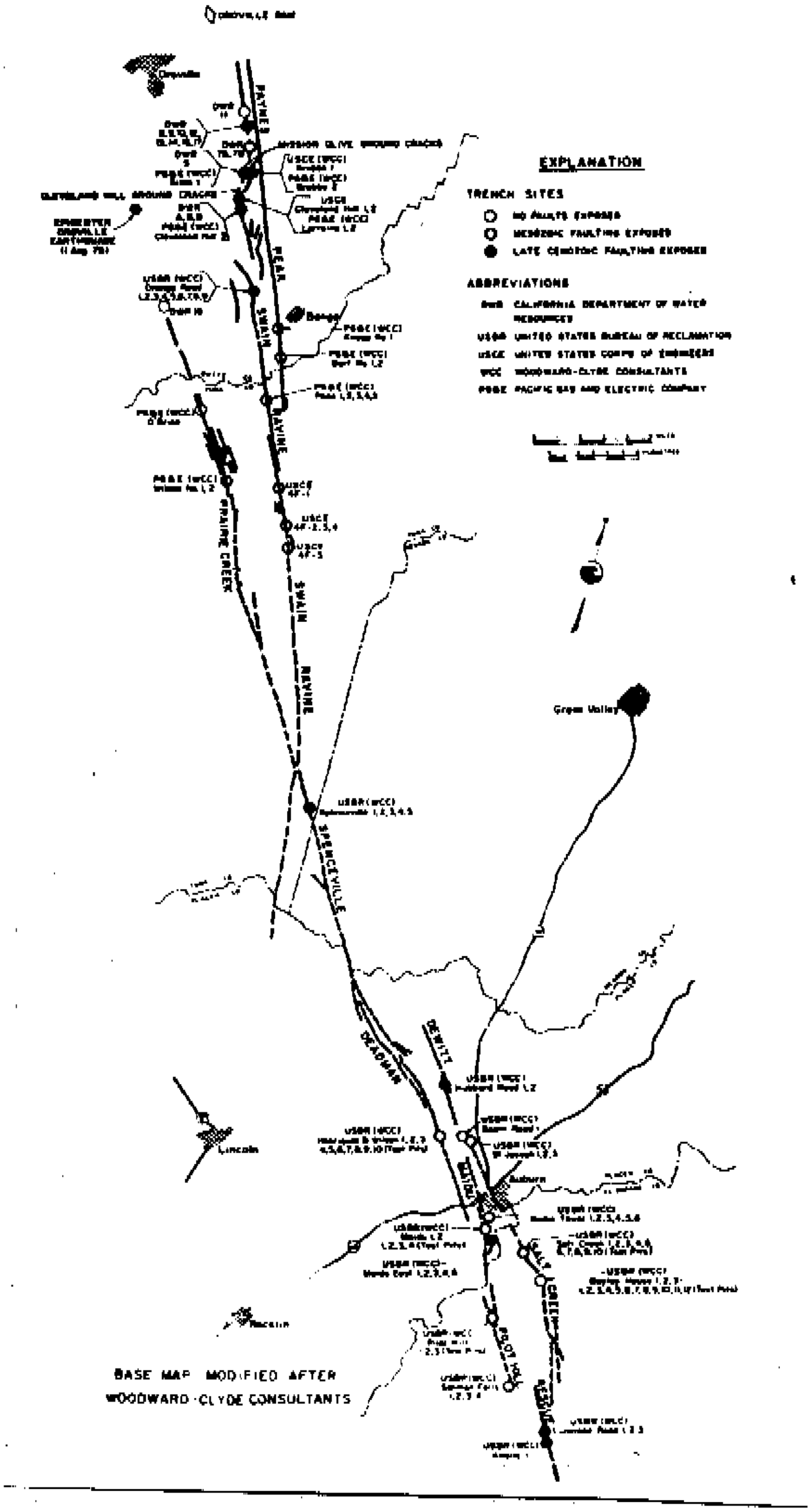

Figure 2 (to FER-147). Major lineaments in the northwestern Sierra Nevada, showing locations of site specific studies evaluating fault recency. Map from CDWR (1979).

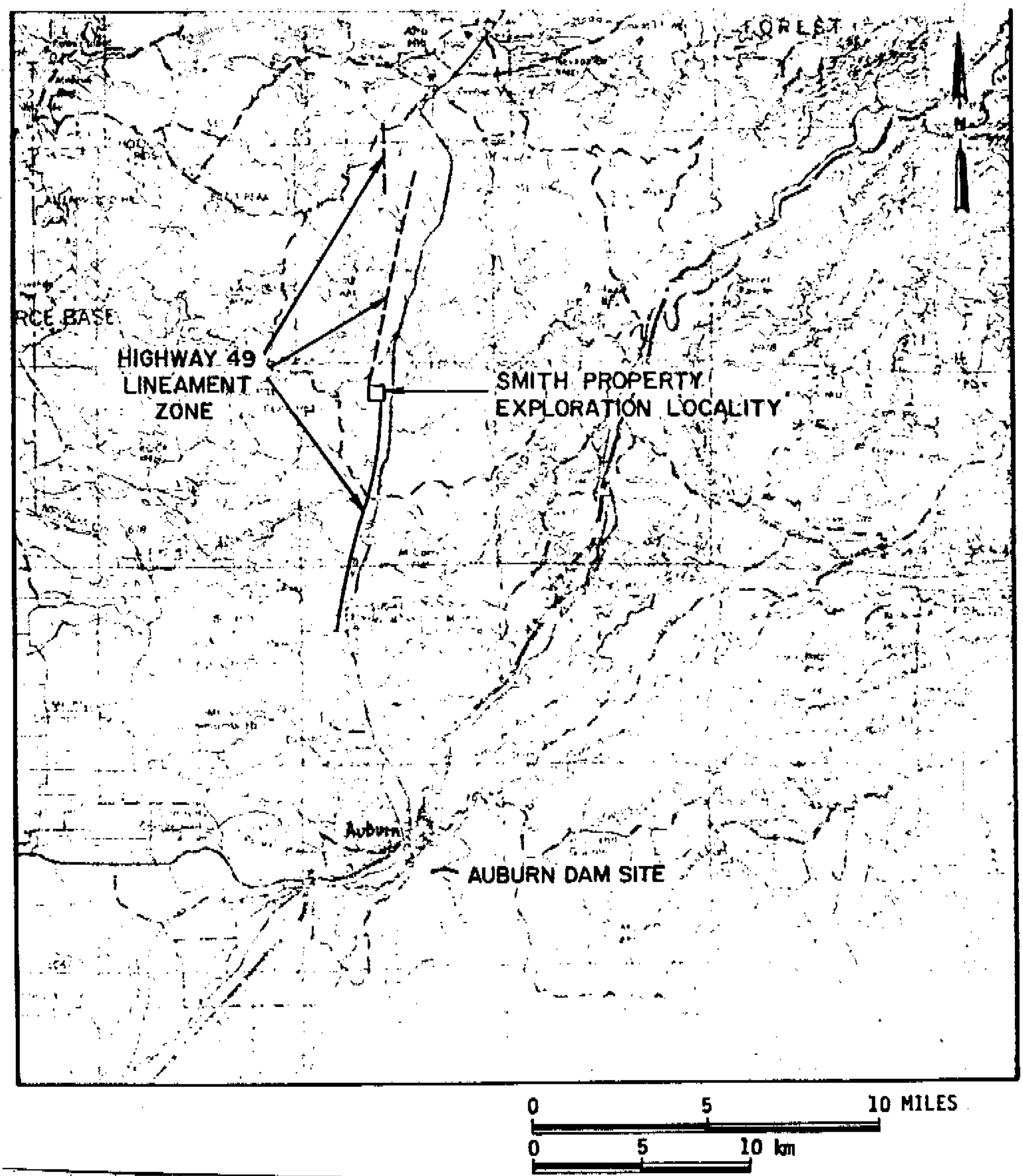

Figure 3 (to FER-147). Generalized map of the Highway 49 lineament, showing the location of the Smith property site. Map from Alt, et al (1977).

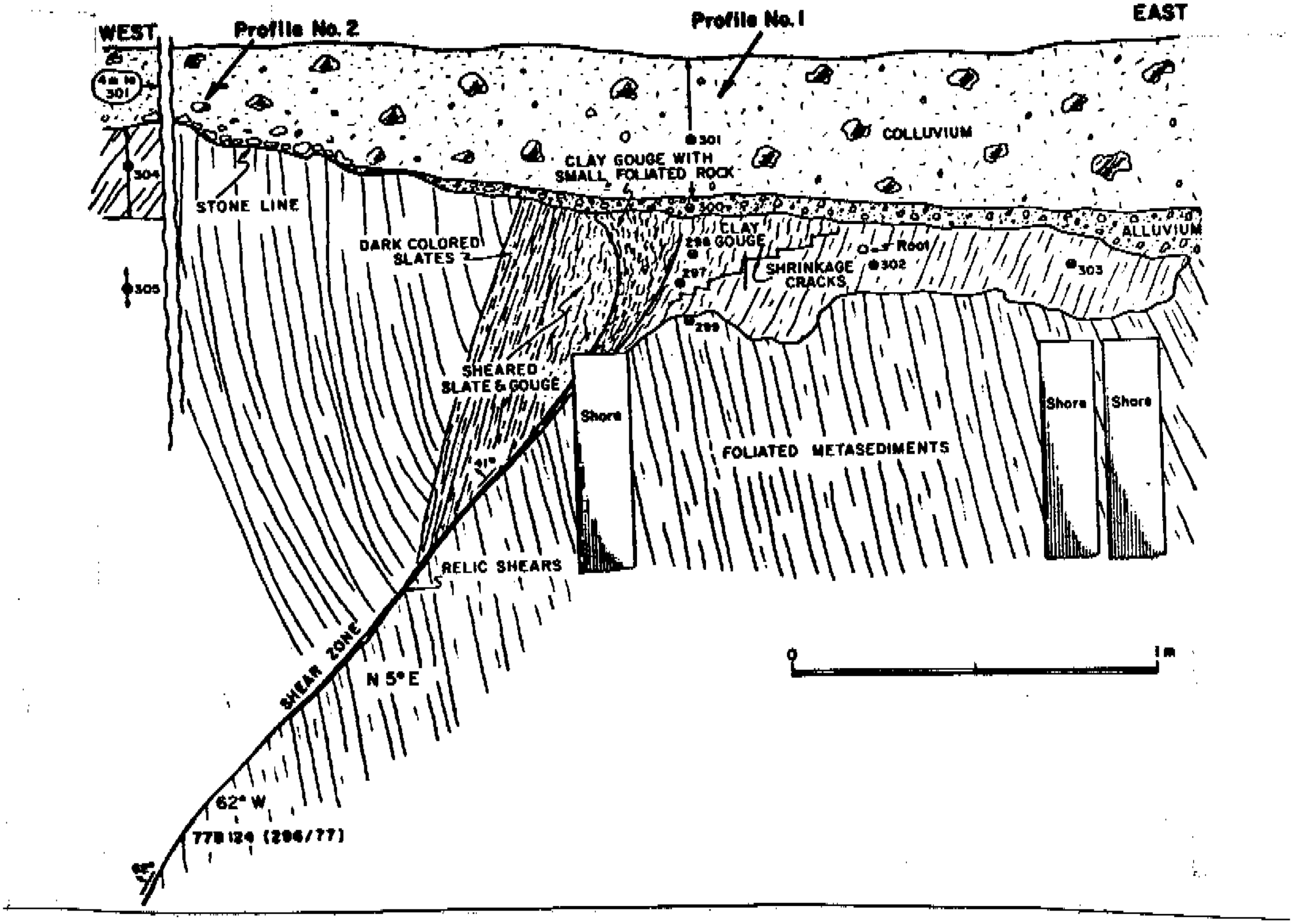

Figure 5 (to FER-147). Log of the primary fault feature exposed in the north wall of trench T_1 (see figure 4). A remnant paleo-B soil horizon is located along the east (right hand)side of the shear. The thin alluvium was assigned an early Holocene age by Borchardt, et al. (1980b). Log from Borchardt, et al. (1980b).

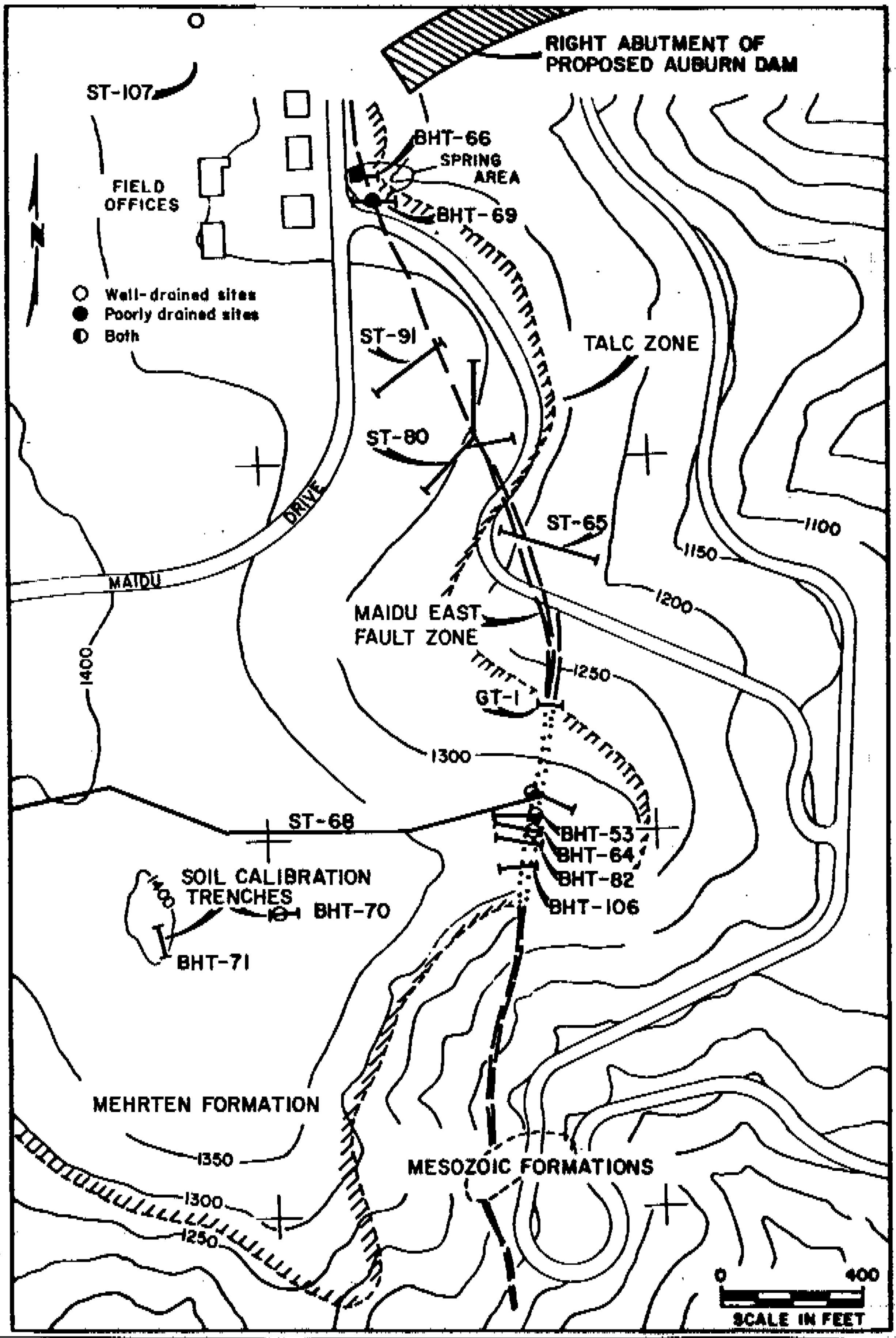

Figure 8a (to FER-147). Detailed map of the Maidu East shear zone, showing locations of trench excavations by USBR and WCC.. Map from Borchardt, et al.,(1980a).

Figure 8b (to FER-147). Map of the proposed Auburn dam area, showing F and T zones mapped by USBR (Frei, et al., 1977). Map from Schwartz, et al. (1977).

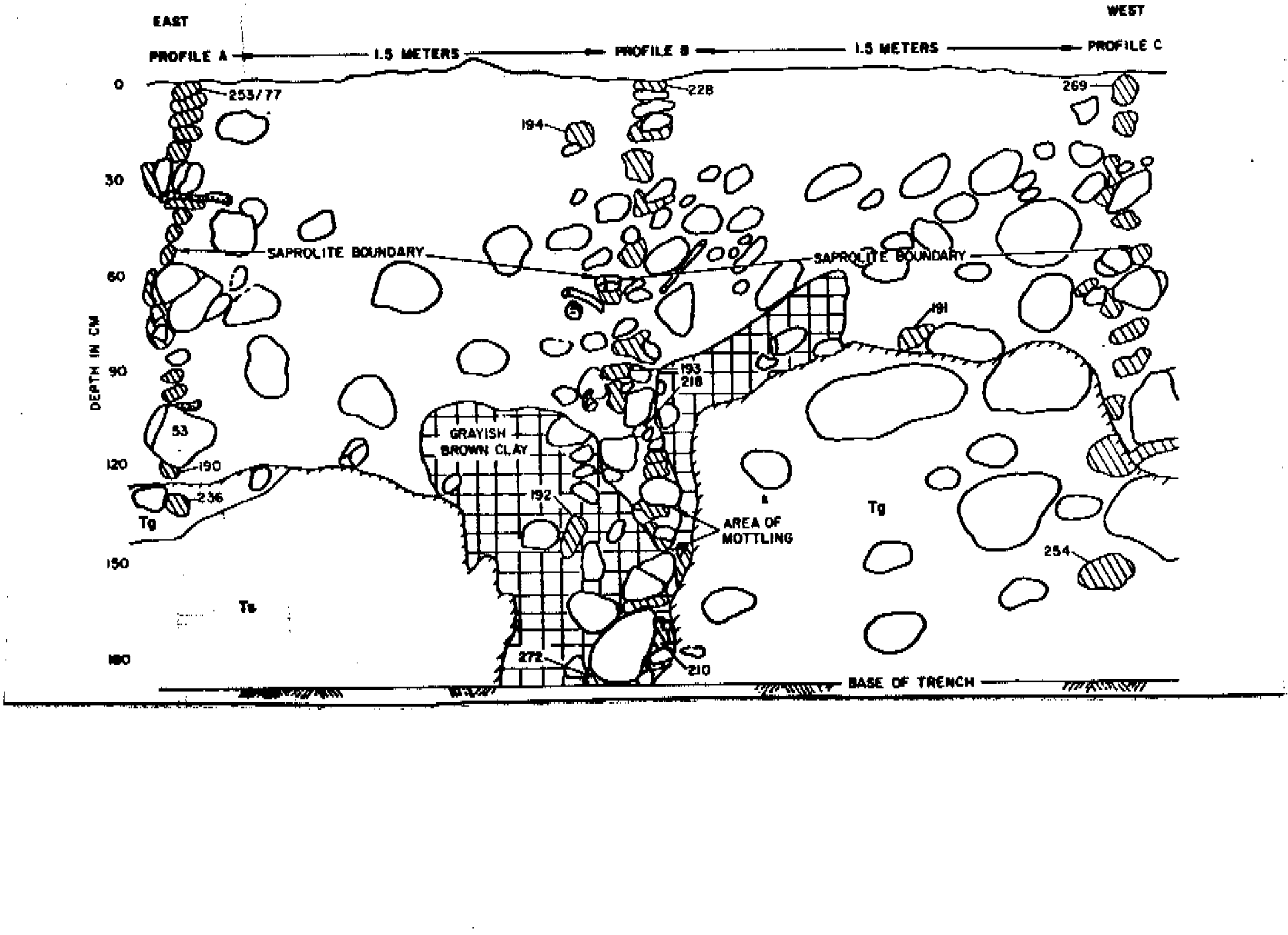

Figure 9 (to FER-147). Log of principal shear within the Maidu East lineament, showing soil-bedrock relationships. Boxed area indicates the "soil tongue" referred to in text. Saprolite boundary is the minimum depth at which saprolites occur. Log from Borchardt, et al. (1980a).

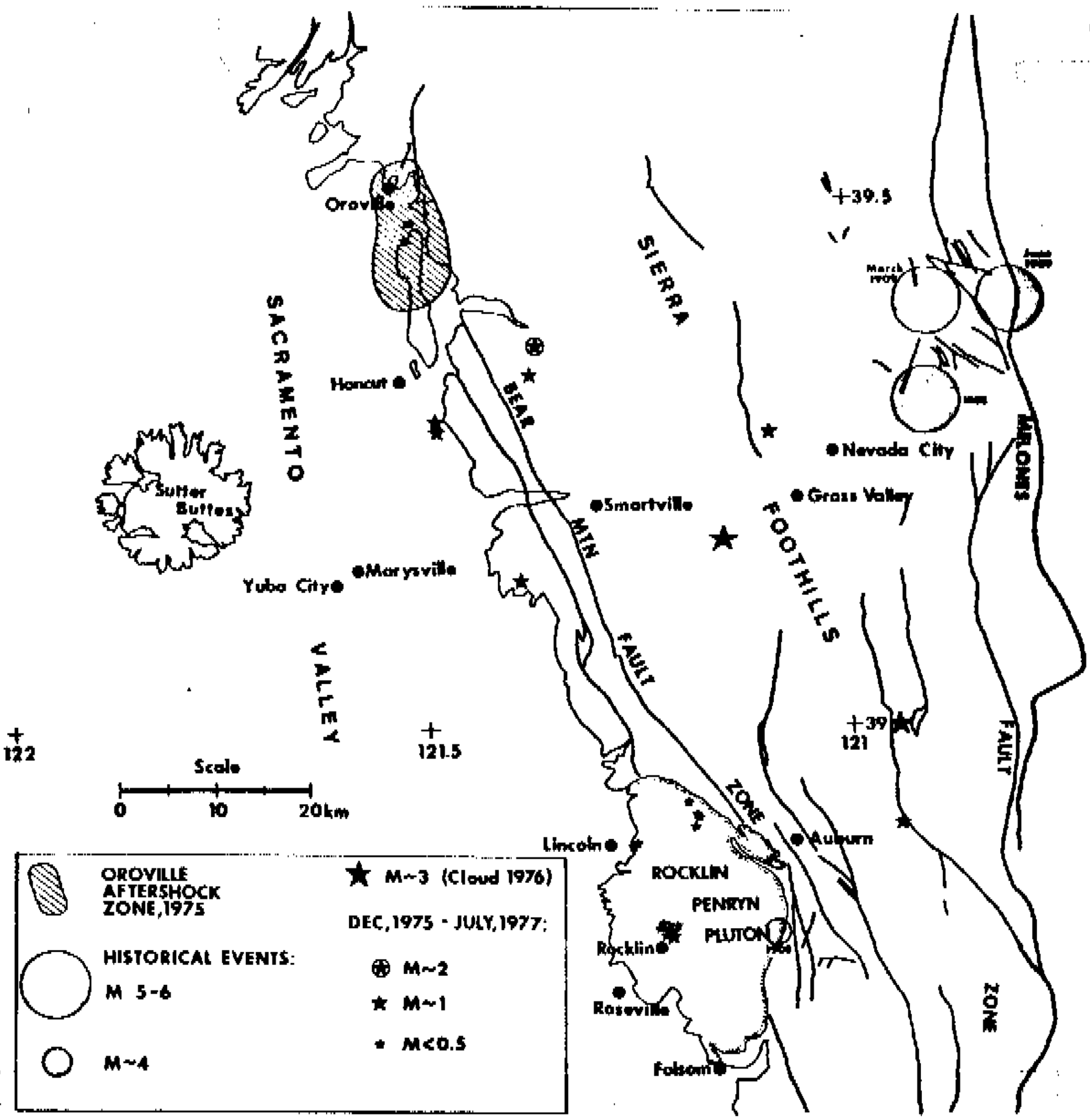

Figure 10 (to FER-147). Map of northern part of Foothills fault system, showing known earthqukkes between Oroville and Folsom. Map from Cramer, et al. (1978).